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## Section 653—Thermoplastic Traffic Stripe

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### 653.1 General Description

This work includes furnishing and applying thermoplastic reflectorized pavement marking compound. Ensure that markings conform to Plan details and locations, these Specifications, and the Manual on Uniform Traffic Control Devices.

Thermoplastic traffic stripe consists of solid or broken (skip) lines, words, and symbols according to Plan color, type, and location.

#### 653.1.01 Definitions

**Thermoplastic Marking Compound:** A compound extruded or mechanically sprayed on the pavement that cools to pavement temperature. When combined with glass spheres it produces a reflectorized pavement marking.

**Short Lines:** Crosswalks, stop bars, arrows, symbols, and crosshatching. Extrude short lines rather than spraying them on. Unless otherwise specified, spray all other lines.

#### 653.1.02 Related References

##### A. Standard Specifications

[Section 652—Painting Traffic Stripe](#)

##### B. Referenced Documents

[QPL 46](#)

Federal Test Method Standard 141, Method 4252

ASTM D 1155

ASTM D 620

ASTM D 570

ASTM D 256

ASTM D 2240

ASTM E 28

ASTM 121

#### 653.1.03 Submittals

Ensure that the producers of the thermoplastic compound and glass spheres furnish to the Department copies of certified test reports showing results of all tests specified in this Section. Also ensure that producers certify that the materials meet the other requirements of this Section by submitting copies of certification at the time of sampling. Final Acceptance, however, will be based on satisfactory test results from samples obtained by the Department before delivery.

### 653.2 Materials

#### A. General Characteristics of Thermoplastic

##### 1. Deterioration

Use thermoplastic material with the following characteristics:

- a. Does not deteriorate upon contact with:
  - Pavement materials
  - Petroleum droppings from traffic
  - Chemicals, such as sodium chloride or calcium chloride, used to prevent formation of ice on roadways or streets
- b. Does not scorch, discolor, or deteriorate if kept at the manufacturer's recommended application temperature, or at least 375 °F (190 °C), for up to 4 hours.
- c. Has a temperature versus viscosity characteristic that remains constant from batch to batch through four re-heatings.

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### 2. Fumes

Use material that in the plastic state does not give off fumes that are toxic or harmful to persons or property.

## B. Detailed Characteristics of Thermoplastic

### 1. Material Composition

Use material binder with the following characteristics:

- A mixture of synthetic resins, with at least one resin that is solid at room temperature, and high boiling point plasticizers
- A total binder content of 18 percent to 35 percent by weight
- A pigmented binder that is well-dispersed and free of dirt, foreign objects, or ingredients that cause bleeding, staining, or discoloration

The binder shall be Type A—alkyd. Ensure that at least 33% of the binder composition or at least 8% by weight of the entire material formulation is a maleic-modified glycerol ester of resin. Ensure that the finished thermoplastic pavement marking material is not adversely altered by contact with oily pavement materials or by contact from oil dropping onto the pavement surface from traffic.

Ensure that the filler has the following characteristics:

- White calcium carbonate or equivalent
- Compressive strength of 5,000 psi (34.5 MPa)

### 2. Suitability for Markings

Use thermoplastic material that is especially compounded for traffic markings and has the following characteristics:

- Prevents markings from smearing or spreading under normal traffic conditions at temperatures below 120 °F (49 °C)
- Gives a uniform cross section, with pigment evenly dispersed throughout the material
- Has a uniform material density and character throughout its thickness
- Allows the stripe to maintain its original dimensions and placement
- Ensures that the exposed surface is free from tack and is not slippery when wet
- Does not lift from the pavement in freezing weather
- Has cold ductility properties that permit normal movement with the road surface without chipping or cracking

### 3. Drying Time

When applied at a temperature range of 400 °F to 425 °F (204 °C – 218 °C) and a thickness of 1/8 in. to 3/16 in. (3 mm to 5 mm), the material shall set to bear traffic in a maximum of 2 minutes when the air temperature is 50 °F ± 3 °F (10 °C ± 2 °C) and shall set to bear traffic in a maximum of 10 minutes when the air temperature is 90 °F ± 3 °F (32 °C ± 2 °C).

### 4. Reflectorization

Ensure that during manufacturing, reflectorizing glass spheres were mixed into the compound to the following specifications:

- At least 16 percent by weight using glass spheres with a minimum refractive index of 1.65
- At least 25 percent by weight using glass spheres with a minimum refractive index of 1.50

## C. Physical Requirements of Thermoplastic

### 1. Color

Confirm the color of thermoplastic as follows:

- a. White thermoplastic material contains at least 8 percent by weight titanium dioxide that meets the requirements of ASTM D 476, Type II, Rutile. The white thermoplastic material shall be pure white and free from dirt or tint. The material, when compared to the magnesium oxide standard using a standard color spectrophotometer according to ASTM D 4960, shall meet the following:

Scale	Definition	Magnesium Oxide Standard	Sample
Rd	Reflectance	100	75 min.

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a	Redness-Greenness	0	-5 to + 5
b	Yellowness-Blueness	0	-10 to + 10

Compare yellow material to match Federal Test Standard Number 595, Color 13538.

### 2. Color Retention

Use thermoplastic stripe tested for color retention as follows:

- a. Test specimens prepared from samples submitted according to ASTM D 620 by the Department Inspector.
- b. Use an ultraviolet light source as specified in the test procedure, or use a 275 watt sunlamp with a built-in reflector.
- c. Ensure that after 100 hours of exposure to the light source, the test specimens show no color change when compared to an unexposed specimen.

### 3. Water Absorption

Ensure that materials have no more than 0.5 percent by weight of retained water when tested by ASTM D 570, procedure (a).

### 4. Softening Point

Ensure that materials have a softening point of at least 175 °F (79 °C) as determined by ASTM E 28.

### 5. Specific Gravity

Ensure that the specific gravity of the thermoplastic compound at 77 °F (25 °C) is between 1.9 to 2.5.

### 6. Impact Resistance

Use material with an impact resistance of at least 10 in-lbs at 77 °F (1.13 N·m at 25 °C), tested as follows:

- a. Heat for 4 hours at 400 °F (204 °C).
- b. Cast into bars of 1 in<sup>2</sup> (625 mm<sup>2</sup>) cross sectional area, 3 in (75 mm) long.
- c. Place with 1 in (25 mm) extending above the vise in a cantilever beam (Izod type) tester using the 25 in-lbs (2.82 N·m) scale. This instrument is described in ASTM D 256.

### 7. Indentation Resistance

Measure the hardness by a Shore Durometer, Type A2, as described in ASTM D 2240. Maintain the temperature of the Durometer, 4.4 lb. (2 kg) load and the specimen at 115 °F (45 °C). Apply the Durometer and 4.4 lb. (2 kg) load to the specimen and the reading shall be between 50 to 75 units, after 15 seconds.

### 8. Low Temperature Stress Resistance

- a. Furnish sample test blocks as follows:
  - 1) Coat the samples using the same method as the planned installation of the compound.
  - 2) Coat the samples with at least 32 in<sup>2</sup> (206 mm<sup>2</sup>) of the compound.
- b. Have the samples tested as follows:
  - 1) Immerse a sample in cold water for one hour.
  - 2) Immediately place the sample in a freezer chest or other insulated cold compartment and maintain at a temperature of -20 °F (-29 °C) for 24 hours.
  - 3) After 24 hours, remove the sample and bring it to normal room temperature.

Following the test, confirm that the sample does not crack, flake, or fail to adhere to the substrate.

### 9. Reheating

Ensure that the compound does not break down, deteriorate, scorch, or discolor if held for 6 hours at the plastic temperature of 425 °F (218 °C); or if reheated up to the plastic temperature 4 times.

### 10. Abrasion Resistance

Have the material tested for abrasion resistance as follows:

- a. Ensure that the maximum loss of the material does not exceed 0.4 grams when subjected to 200 revolutions on a Taber Abraser at 77 °F (25 °C), using H-22 Calibrade wheels that are weighted to 500 grams.
- b. Keep the wearing surface wet with distilled water throughout the test.

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- c. Prepare the panel by forming a representative lot of material at a thickness of 0.125 in. (3.18 mm) on a 4 in (100 mm) square steel plate with a thickness of 0.050 ± 0.001 in (1.27 mm ± 0.03 mm), on which a primer has been previously applied.

11. Yellowness Index

The white thermoplastic material shall not exceed a yellowness index of 0.12 according to AASHTO T 250.

12. Flowability

After heating the thermoplastic material for 240 ± 5 minutes at 425 °F ± 3 °F (218 °C ± 2 °C) and testing the flowability, ensure that the white thermoplastic has a maximum of 21 percent residue according to AASHTO T 250.

13. Flowability-Extended Heating

After heating the thermoplastic material for 8.0 ± 0.5 hours at 425 °F ± 3 °F (218 °C ± 2 °C), while stirring the last 6 hours and testing for flowability, ensure that the thermoplastic has a maximum percent residue of 28 according to AASHTO T 250.

14. Storage Life

The material shall meet the requirements of this specification for 1 year. Ensure that the thermoplastic melts uniformly with no evidence of skins or unmelted particles during the 1-year period.

**D. Physical Requirements of Glass Spheres**

1. Premixed Glass Spheres

Ensure that the compound has been manufactured with glass spheres in the proportion specified in [Subsection 653.2.B.4, “Reflectorization.”](#) The glass spheres contained in the material shall meet the following requirements:

- a. Index of Refraction. Determine the index of refraction of the premixed glass spheres by the liquid immersion method at 77 °F (25 °C).
- b. Roundness. Ensure that the minimum percentages of premixed glass spheres are true spheres according to the following table:

<b>Percent of Premixed Glass Spheres That are True Spheres (when tested according to ASTM D 1155)</b>		
<b>Minimum Index of Refraction</b>	<b>Percent of Overall Beads</b>	<b>Percent of Beads Retained on any Sieve</b>
1.65	At least 75%	At least 70%
1.50	At least 70%	At least 60%

- c. Imperfections. Ensure that no more than 5 percent of the spheres show air inclusions, bubbles, lap lines, chill wrinkles, or other imperfections when viewed through a 60-power microscope in the refractive index liquid.
- d. Foreign Matter. Ensure that the quantity of foreign matter does not exceed 1 percent.
- e. Gradation. Have the beads tested using ASTM: D 1214 to ensure they have the following gradations:

<b>U.S. Sieve Standard Sieve Size</b>	<b>Percent Passing</b>
No. 16 (1.18 mm)	100
No. 30 (600 μm*)	60 to 90
No. 50 (300 μm)	15 to 40
No. 80 (180 μm)	0 to 10
No. 100 (150 μm)	0 to 5
*μ = micro meter	

- f. Chemical Resistance. Use material manufactured with glass spheres that withstand immersion in water and acids without corroding or etching, and withstand sulfides without darkening or decomposing.

Have the chemical resistance tested by placing a 3 g to 5 g sample in each of three glass beakers or porcelain dishes and immersing as follows:

- Cover the first with distilled water.

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- Cover the second with a 3N solution of sulfuric acid.
- Cover the third with a solution of 50 percent sodium sulfide, 48 percent distilled water, and 2 percent Aerosol 1B or similar wetting agent.

Ensure that after one hour no darkening, hazing, or other evidence of instability is evident when examined microscopically.

### 2. Drop-On Glass Spheres

Ensure that these spheres meet the requirements of [Subsection 652.2](#).

### E. Requirements of Sealing Primer

Place the particular type of two-part epoxy binder-sealer at the application rate as recommended in writing by the thermoplastic material manufacturer.

#### 653.2.01 Delivery, Storage, and Handling

Use material delivered in 50 lb (22.7 kg) unit cardboard containers or bags strong enough for normal handling during shipment and on-the-job transportation without loss of material.

Ensure that each unit container is clearly marked to indicate the following:

- Color of the material
- Process batch number or similar manufacturer's identification
- Manufacturer's name
- Address of the plant
- Date of manufacture

### 653.3 Construction Requirements

#### 653.3.01 Personnel

General Provisions 101 through 150.

#### 653.3.02 Equipment

Depending on the marking required, use hand equipment or truck-mounted application units on roadway installations.

##### A. Spray Application Machine

Ensure that each spray application machine is equipped with the following features:

- Parts continuously mix and agitate the material.
- Truck-mounted units for lane, edge, and center lines can operate at a minimum of 5 mph (8 kph) while installing striping.
- Conveying parts between the main material reservoir and the shaping die or gun prevent accumulation and clogging.
- Parts that contact the material are easily accessible and exposable for cleaning and maintenance.
- Mixing and conveying parts, including the shaping die or gun, maintain the material at the plastic temperature with heat transfer oil or electrical element controlled heat. Do not use an external source of direct heat.
- Parts provide continuously uniform stripe dimensions.
- Applicator cleanly and squarely cuts off stripe ends and applies skip lines. Do not use pans, aprons, or similar appliances that the die overruns.
- Parts produce varying widths of traffic markings.
- Applicator is mobile and maneuverable enough to follow straight lines and make normal curves in a true arc.

##### B. Automatic Bead Dispenser

Apply glass spheres to the surface of the completed stripe using a dispenser attached to the striping machine to automatically dispense the beads instantaneously upon the installed line. Synchronize the glass sphere dispenser cutoff with the automatic cutoff of the thermoplastic material.

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### C. Special Kettles

Use special kettles for melting and heating the thermoplastic material. Kettles equipped with automatic thermostatic control devices provide positive temperature control and prevent overheating. Ensure that the applicator and kettles are equipped and arranged according to the requirements of the National Fire Underwriters.

### D. Hand Equipment

Use hand equipment for projects with small quantities of lane lines, edge lines, and center lines, or for conditions that require the equipment. Use hand equipment approved by the Engineer.

Ensure that hand equipment can hold 150 lbs (68 kg) of molten material and is maneuverable to install crosswalks, arrows, legends, lane, edge, and center lines.

### E. Auxiliary Vehicles

Supply the necessary auxiliary vehicles for the operation.

### 653.3.03 Preparation

General Provisions 101 through 150.

### 653.3.04 Fabrication

General Provisions 101 through 150.

### 653.3.05 Construction

#### A. General Application

Thoroughly clean pavement areas to be striped. Use hand brooms, rotary brooms, air blasts, scrapers, or other approved methods that leave the pavement surface clean and undamaged. Take care to remove all vegetation and road film from the striping area. All new Portland Cement Concrete pavement surfaces shall be mechanically wire brushed or abrasive cleaned to remove all laitance and curing compound before being striped.

Lay stripe with continuous uniform dimensions.

Apply the type of stripe at each location according to the Plans, using one of the following methods:

- Spray techniques
  - Extrusion methods wherein one side of the shaping die is the pavement, and the other three sides are contained by or are part of the suitable equipment to heat and control the flow of material.
1. Temperature  
Apply thermoplastic traffic stripe only when the pavement temperature in the shade is above 40 °F (4 °C).  
To ensure optimum adhesion, install the thermoplastic material in a melted state at the manufacturer's recommended temperature but not at less than 375 °F (190 °C).
  2. Moisture  
Do not apply when the surface is moist. When directed by the Engineer, perform a moisture test on the Portland cement concrete pavement surface. Perform the test as follows:
    - a. Place approximately 1 yd<sup>2</sup> (1m<sup>2</sup>) of roofing felt on the pavement surface.
    - b. Pour approximately 1/2 gallon (2 L) of molten thermoplastic onto the roofing felt.
    - c. After 2 minutes, lift the roofing felt and inspect to see if moisture is present on the pavement surface or underside of the roofing felt.
    - d. If moisture is present, do not proceed with the striping operation until the surface has dried sufficiently to be moisture free.
  3. Binder-Sealer  
To ensure optimum adhesion, apply a binder-sealer material before installing the thermoplastic in each of the following cases:
    - Extruded thermoplastic
    - Where directed by the Engineer for sprayed thermoplastic
    - Old asphaltic concrete pavements with exposed aggregates

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- Portland cement concrete pavements as directed by the Engineer

Ensure that the binder-sealer material forms a continuous film that mechanically adheres to the pavement and dries rapidly. Use a binder-sealer currently in use and recommended by the thermoplastic material manufacturer according to [QPL 46](#).

To ensure optimum adhesion, apply a two-part epoxy binder-sealer on all Portland cement concrete pavements for either sprayed or extruded thermoplastic material.

Apply the epoxy binder-sealer immediately in advance of, but concurrent with, the application of the thermoplastic material. Apply in a continuous film over the pavement surface.

### 4. Bonding to Old Stripe

The old stripe may be renewed by overlaying with new material. Ensure the new material bonds to the old line without splitting or cracking.

### 5. Offset from Construction Joints

Off-set longitudinal lines at least 2 in (50 mm) from construction joints of Portland cement concrete pavements.

### 6. Crosswalks, Stop Bars, and Symbols

Make crosswalks, stop bars, and symbols at least 3/32 in (2.4 mm) thick at the edges and no more than 3/16 in (4.8 mm) thick at the center.

### 7. Film Thickness

a. Maintain the following minimum average film thicknesses on all open graded asphalt concrete friction courses:

- 0.120 in (3.0 mm)\* for lane lines
- 0.090 in (2.3 mm)\* for edge lines
- 0.150 in (3.8 mm)\* for gore area lines

b. Maintain the following minimum average film thicknesses on all other pavement types:

- 0.090 in (2.3 mm)\* for lane lines
- 0.060 in (1.5 mm)\* for edge lines
- 0.120 in (3.0 mm)\* for gore area lines

(See below for ‘\*’ reference.)

Compute the minimums by the amount of material used each day, as follows:

<b>(For 5 in wide stripe)</b>	
* Average Film Thickness (in) =	$[(\text{lbs used}) \div (\text{total linear feet})] \times 0.236$
<b>(For 125 mm wide stripe)</b>	
*Average Film Thickness (mm) =	$[(\text{kg used}) \div (\text{total linear meters})] \times 4.0$
<b>(For 10 in wide stripe)</b>	
* Average Film Thickness (in) =	$[(\text{lbs used}) \div (\text{total linear feet})] \times 0.118$
<b>(For 250 mm wide stripe)</b>	
* Average Film Thickness (mm) =	$[(\text{kg used}) \div (\text{total linear meters})] \times 2.0$

### 8. Glass Spheres

- Apply glass spheres to installed stripe surface at a minimum rate of 14 lbs of spheres to each 100 square feet ((700 g/m<sup>2</sup>) of thermoplastic material.
- Apply the glass sphere top-coating with a pressure-type gun specifically designed for applying glass spheres that will embed at least one-half of the sphere’s diameter into the thermoplastic immediately after the material has been applied to the pavement.

## B. Removing Existing Stripe

Remove existing stripe according to [Section 656](#).

Remove 100 percent of existing traffic stripe from:

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- Portland cement concrete pavement where the new stripe will be placed at the same location as the existing marking
- Pavement where the new stripe will be placed at a different location from the existing markings

### C. Tolerance and Appearance

No traffic stripe shall be less than the specified width and shall not exceed the specified width by more than 1/2 in (13mm). The length of the 10 ft (3 m) segment for skip stripe and the 30 ft (9 m) gap between segments may vary plus or minus 1 ft (300 mm). The alignment of the stripe shall not deviate from the intended alignment by more than 1 in (25 mm) on tangents and on curves up to and including 1 degree (radius of 1745 m or greater). On curves exceeding 1 degree (radius less than 1745 m), the alignment of the stripe shall not deviate from the intended alignment by more than 2 in (50 mm).

Stop work when deviation exceeds the above dimensions, and remove the nonconforming stripe.

### 653.3.06 Quality Acceptance

Segments of the thermoplastic traffic stripe that have been placed according to the Plans and Specifications may be accepted 30 days after the required work is complete in that segment.

If thermoplastic traffic stripe fails to meet Plan details or Specifications or deviates from stated dimensions, correct it at no additional cost to the Department. If removal of pavement markings is necessary, perform it according to Section 656 and place it according to this Specification. No additional payment will be made for removal and replacement of unsatisfactory striping.

### 653.3.07 Contractor Warranty and Maintenance

After segments are accepted, the Contractor will be relieved of maintenance on those segments.

## 653.4 Measurement

When stripe will be paid for by the square yard (meter), the actual number of square yards (meters) painted will be measured. The space between the stripes will be included in the overall measurement.

Linear measurements may be made by electronic measuring devices attached to a vehicle.

Thermoplastic traffic stripe, complete in place and accepted, is measured as follows:

### A. Solid Traffic Stripe

Stripe is measured by the linear foot (meter), linear mile (kilometer), or square yard (meter). Breaks or omissions in solid lines or stripes at street or road intersections are not measured for payment.

### B. Skip Traffic Stripe

Skip stripe is measured by the gross linear mile (kilometer) as specified. The unpainted space between the painted stripes is included in the overall measurement if the Plan ratio of one to three (10 ft [3 m] segment and 30 ft [9 m] gap or other patterns as designated on the Plans) remains uninterrupted. Measurement begins and ends on a stripe.

### C. Words and Symbols

Each word or symbol complete according to Plan dimensions is measured by the Unit.

### 653.4.01 Limits

General Provisions 101 through 150.

## 653.5 Payment

Payment is full compensation for the Work under this section, including:

- Cleaning and preparing surfaces
- Furnishing all materials
- Applying, curing, and protecting stripe
- Protecting traffic, including providing necessary warning signs
- Furnishing tools, machines, and other equipment necessary to complete the Item

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Measurement and payment for removing pavement markings will be according to [Section 656](#) when shown in the Proposal as a payment Item. Otherwise, removal will not be paid for separately, but will be included in the payment for other Work under this section.

Payment will be made under:

Item No. 653	Thermoplastic solid traffic stripe, __ in (mm), (color)	Per linear foot (meter)
Item No. 653	Thermoplastic solid traffic stripe, __ in (mm), (color)	Per linear mile (kilometer)
Item No. 653	Thermoplastic skip traffic stripe, __ in (mm), (color)	Per gross linear foot (meter)
Item No. 653	Thermoplastic skip traffic stripe, __ in (mm), (color)	Per gross linear mile (kilometer)
Item No. 653	Thermoplastic pavement markings, words, and symbols (color), type _____	Per each
Item No. 653	Thermoplastic traffic stripe	Per square yard (meter)

### 653.5.01 Adjustments

General Provisions 101 through 150.